Sugarcane Response to Water Table, Periodic Flood, and Foliar Nitrogen on Organic Soil

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ABSTRACT

Sugarcane (*Saccharum* spp.) is routinely exposed to periodic floods and high water tables in Florida's Everglades Agricultural Area. Learning sugarcane responses to these conditions will help improve yields. This study evaluated the effects of constant water-table depths, periodic floods, and N on cane and sucrose yields of two sugarcane cultivars. In 2001 and 2002, two foliar N and four water treatments were applied to the first two crop-growth cycles (plant and first-ratoon crops) of 'CP 72-2086' and 'CP 80-1827' in lysimeters filled with Pahokee muck soil. Constant water-table depths were 23, 37, and 51 cm. A fourth treatment was flooding for 2 d in each of eight 14-d cycles per year; otherwise its water-table depth was 44 cm. Foliar N did not consistently affect yields. In nonflooded treatments across cultivars and crop growth cycles, for every centimeter increase in water-table depth, theoretical recoverable sucrose decreased by 0.13 g kg^{-1}, and cane and sucrose yields increased by 0.16 and 0.02 kg m^{-2}, respectively. By cultivar and crop-growth cycle, the only significant linear responses to nonflooded water-table treatments were in the first-ratoon crop, where for each centimeter increase in water-table depth, cane and sucrose yields increased by 0.38 and 0.04 kg m^{-2}, respectively. Periodic flooding increased cane and sucrose yields in the plant crop and sustained or improved these yields in the first-ratoon crop. After rains, allowing floods to remain for up to 2 d may improve yields and reduce P discharge to the Everglades.

T HE Everglades Agricultural Area (EAA) is a 280 000-ha basin of Histosols that lie on limestone bedrock in the northern region of the historic Everglades in Florida. Sugarcane is grown on about 146 000 ha in the EAA (Glaz, 2002). Before construction of an extensive public/private system of canals through the northern Everglades, the EAA was flooded most of the time (Snyder and Davidson, 1994). Until recently, farmers used the canal system to effectively manage desired water-table depths of 40 to 95 cm in sugarcane fields (Omary and Izuno, 1995).

The canal system still helps control water tables in EAA sugarcane fields. However, it is now common for sugarcane to be exposed to high water tables and periodic floods in all crop-growth cycles. Three major reasons for the reduced effectiveness of the canal system are the rising of water tables in the EAA by about 10 cm for each centimeter of rainfall, loss of soil depth

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due to soil subsidence, and voluntary and regulated pumping restrictions to control P discharge from the EAA. These factors were described previously in more detail (Glaz et al., 2004).

Previous research found that some sugarcane genotypes yielded well in Florida at water-table depths of ≤30 cm. In a field study, Kang et al. (1986) compared sugar concentrations and cane yields of 16 clones of sugarcane (*Saccharum* spp.), one of *S. robustum*, one of *S. officinarum*, and one of *Ripidium* spp. at field water-table depths of 30 and 56 cm. They found that, at the 30-cm water-table depth, in the plant-cane and first-ratoon crops, respectively, overall mean sugar concentrations were 15.7 and 17.6% higher, and overall mean cane yields were 27.5 and 25.3% higher. In a field study, Glaz et al. (2002) maintained nine cultivars under summer water-table depths of <15 cm and between 15 and 38 cm for the plant through the second-ratoon crops. Overall sucrose yields under the shallow water table (<15 cm) were 91.7% of those at the deeper water table, and sucrose yield of one cultivar, CP 80-1743, was reduced by 25% by the shallow water table. However, sucrose yields of two cultivars, CP 72-2086 and CP 82-1172, were not affected by water-table depth. In a lysimeter study with two genotypes, Glaz et al. (2004) reported yield losses attributable to periodic floods of 1-wk duration and drainage to 50 cm compared with a continuous water-table depth of 50 cm for CP 95-1376, a genotype that did not form constitutive stalk aerenchyma. As water-table depth during nonflood periods increased from 16 to 50 cm, yields of CP 95-1376 increased linearly. Yields of CP 95-1429, which formed constitutive stalk aerenchyma, were not affected by periodic floods or water-table depth.

Under routine growing conditions, it is thought that microbial oxidation of organic soils in the EAA makes excessive N available to sugarcane. Annual rate of soil loss in the EAA is about 1.3 cm (Shih et al., 1998). Terry (1980) estimated that 686 kg N ha^{-1} are mineralized for each cm of soil lost to microbial oxidation. Thus, about 892 kg N ha^{-1} are mineralized annually.

Coale et al. (1993) estimated annual N accumulation by a sugarcane crop on Florida Histosols at 142 kg ha^{-1}, well below the estimated 892 kg ha^{-1} that is mineralized. However, the recent discovery by Morris et al. (2004) that microbial oxidation was controlled by periodic floods and drainage to a depth of 16 cm raises the question of whether intervals of flood and drainage to shallow depths in EAA fields may result in periods of insufficient N availability for optimum sugarcane yields. Adding to this concern was the report by Cisar

et al. (1992) that visual quality and clipping yield of St. Augustinegrass (*Stenotaphrum secundatum* [Walt.] Kuntze) grown on an EAA Histosol at a water-table depth of 30 cm were improved by bi-monthly applications of 50 kg N ha^{-1}.

Farmers in the EAA must sustain low levels of P discharge to comply with efforts to restore the Everglades. Phosphorus movement from farms in the EAA is decreased by reducing the quantity and rate of water discharged from farms to public canals (Sievers et al., 2003). One strategy to achieve reductions in phosphorus discharge is to allow water tables to drop more by evapotranspiration and less by pumping to public canals (Daroub, S.H., T.A. Lang, O.A. Diaz, M. Chen, and J.D. Stuck, unpublished data, 2004).

Because integrative information on water-table depth, periodic flooding, and foliar N fertilization is lacking, the current investigation was undertaken. The purpose of this study was to evaluate the effects of three water-table depths, periodic floods, and foliar N fertilization on cane and sucrose yields of two sugarcane cultivars.

MATERIALS AND METHODS

Sixteen custom-made fiberglass tanks, equipped as lysimeters, were placed into the ground and filled with Pahokee muck soil (Euic, hyperthermic Lithic Haplosaprist). Lysimeters were 1.8 m wide by 3.0 m long by 0.9 m deep and placed where there was no shade. These lysimeters were equipped and operated with pumps, solenoids, and floats to maintain desired water-table depths (Glaz et al., 2004). Soil samples drawn from the upper 15-cm were analyzed for pH (water) and water-extractable P and K (Sanchez, 1990). Based on soil-test recommendations (Sanchez, 1990), fertilizers were banded in the furrows with the planted sugarcane at rates of 37 and 250 kg ha^{-1} of P and K, respectively, and at rates of 0.9, 0.9, 0.9, 2.3, 0.9, and 0.9 kg ha^{-1} of B, Cu, Fe, Mn, Mo, and Zn, respectively. The same rates of P and K were applied on the rows in the first-ratoon crop in January 2002.

Sugarcane was transplanted on 20 March (Replication 1), 23 March (Replication 2), 28 March (Replication 3), and 2 April 2001 (Replication 4). Two rows of recently sprouted sugarcane plants were transplanted 15 cm apart within rows in the lysimeters. Inter-row spacing was 1.5 m. One row in each lysimeter was randomly planted with sugarcane cultivar CP 72-2086 (Miller et al., 1984) and the other row with sugarcane cultivar CP 80-1827 (Glaz et al., 1990). When this study was planted in 2001, CP 72-2086 and CP 80-1827 were the second and fifth most widely planted sugarcane cultivars in Florida, respectively (Glaz, 2002).

After transplanting, lysimeters were maintained at water-table depths of about 20 cm until 12 Apr. 2001 and then at about 40 cm until 29 May 2001, when the four water-table treatments were initiated. Three treatments were constant target water-table depths of 23, 37, and 51 cm. These water-table depths were maintained until the first-ratoon harvest. Most measured and target water-table depths were similar in both crop-growth cycles, except the 23-cm depth, which was 7 cm too deep in the plant crop and 7 cm too shallow in the first-ratoon crop (Table 1). The 51-cm depth was chosen because it is a desired commercial depth, and the two incrementally shallower depths were chosen because such depths are becoming increasingly common for extended durations in commercial fields. Similar water-table depths were combined with 7-d periodic floods in a previous study (Glaz et al., 2004). The fourth treatment was a

Table 1. Target and measured water-table depths in 2001 (plant crop) and 2002 (first-ratoon crop).†

	Water-table depth (cm)				
	2001		2002		Combined years
Target water table	Mean	SEM	Mean	SEM	
23 cm	30.5	2.0	16.0	0.4	23.3
37 cm	39.1	1.5	34.6	0.5	36.8
51 cm	52.9	1.3	50.6	0.5	51.8
44 cm and flood‡	44.7	1.7	42.0	0.8	43.4

† Water measurements for 2001 were from 29 May to 3 Dec. 2001 and for 2002 were from 3 Dec. 2001 to 2 Dec. 2002.
‡ Flood duration was 2 d. Flood frequency was every 14 d from 5 June to 12 Sept. 2001 and from 26 Feb. to 9 June 2002.

constant target water-table depth of 44 cm, except during a 16-wk period each year. During these 16 wk, the fourth treatment was flooded 2 of every 14 d for eight consecutive 14-d flood–drain cycles. Flood–drain cycles of periodically flooded treatments began when mean plant height was approximately 80 cm. Plant height was measured as the distance from the soil surface to the junction of the leaf blade and leaf sheath of the uppermost fully expanded leaf. The first day of the eight consecutive flood–drain cycles was 29 May 2001 in the plant crop and 26 Feb. 2002 in the first-ratoon crop. Mean daily temperatures during the flood–drain periods in 2001 and 2002 were 26.2 and 23.8°C, respectively. During flood, water height ranged from the soil surface to about 4 cm above the soil surface. Flood durations of 2 d were chosen because in a previous study, flood durations of 7 d caused substantial yield losses to one of two genotypes (Glaz et al., 2004).

The experiment also included foliar applications of urea (46–0–0) at N rates per application of 0.0 and 5.6 kg ha^{-1}. Urea was applied to all water-table treatments eight times each crop-growth cycle on the day before application of periodic floods. Each row in each lysimeter was divided in half, and N was applied by hand sprayer to one half of the row and not to the other half. In one corner of each lysimeter, a large pipe extended above the soil surface. If a pipe was present, the row length of N treatments was 1.3 m; the row length of N treatments was 1.5 m if there was no pipe.

Each year, all sugarcane stalks were cut at the soil surface from the entire row of each lysimeter. Immature stalks were discarded. The mean number of stalks harvested per CP 72-2086 and CP 80-1827 treatment was 14 and 11 m^{-1} of row, respectively. After removal of the top four internodes, stalks were weighed to determine cane yield measured as kg m^{-2}. All stalks were milled to extract juice and determine theoretical recoverable sucrose (TRS), measured as g sucrose kg^{-1} cane, calculated using a previously described procedure (Legendre, 1992). Sucrose yield, measured as kg m^{-2}, was calculated as:

$$\text{Sucrose yield} = (\text{TRS} \times \text{cane yield})/1000$$

The plant crop was harvested on 3 Dec. 2001, and the first-ratoon crop was harvested on 2 to 3 Dec. 2002.

Four replications of water-table treatments were arranged as main plots (lysimeters) in a randomized complete-block design. Cultivars were arranged as split plots (rows) in lysimeters. Foliar N applications were arranged as split-split plots. Statistical analyses were performed with PROC MIXED using SAS (SAS Institute, 2003). Data were analyzed for each crop-growth cycle separately, and analyses were also conducted with the combined data of the plant and first-ratoon crops treating crop-growth cycles as repeated measures. Based on procedures described by Tao et al. (2002), the unstructured model with variance components banded [type = Un(1)] was

Table 2. Probabilities of F values of fixed effects for yields of theoretical recoverable sucrose (TRS), cane, and sucrose for two sugarcane genotypes exposed to two N and four water-table treatments in the plant crop (2001) and in the first-ratoon crop (2002).

Fixed effect	Plant crop (2001)			First-ratoon crop (2002)			Combined 2001 and 2002		
	TRS	Cane	Sucrose	TRS	Cane	Sucrose	TRS	Cane	Sucrose
Water table (W)	0.14	<0.01**	<0.01**	0.02*	<0.01**	0.01**	<0.01**	<0.01**	<0.01**
W linear	0.03*	0.44	0.67	0.06	<0.01**	<0.01**	<0.01**	<0.01**	0.03*
Cultivar (C)	<0.01**	<0.01**	<0.01**	<0.01**	0.24	0.68	<0.01**	<0.01**	<0.01**
W × C	0.69	0.27	0.25	0.38	0.04*	0.07	0.67	0.06	0.07
W linear × C	0.49	0.79	0.84	0.97	0.02*	0.03*	0.58	0.28	0.33
Nitrogen (N)	0.57	0.28	0.34	0.61	0.85	0.90	0.80	0.42	0.45
W × N	0.76	0.45	0.44	0.49	0.06	0.05*	0.57	0.18	0.15
W linear × N	0.77	0.66	0.66	0.88	0.38	0.37	0.76	0.91	0.88
C × N	0.61	0.45	0.52	0.28	0.15	0.13	0.99	0.15	0.18
W × C × N	0.68	0.70	0.70	0.76	0.49	0.52	0.89	0.47	0.46
Crop cycle (Y)	–	–	–	–	–	–	<0.01**	<0.01**	<0.01**
W × Y	–	–	–	–	–	–	0.06	0.03*	0.03*
W linear × Y	–	–	–	–	–	–	0.84	0.09	0.13
C × Y	–	–	–	–	–	–	0.92	<0.01**	<0.01**
W × C × Y	–	–	–	–	–	–	0.71	0.33	0.42
N × Y	–	–	–	–	–	–	0.51	0.31	0.38
W × N × Y	–	–	–	–	–	–	0.96	0.31	0.36
C × N × Y	–	–	–	–	–	–	0.40	0.87	0.79
W × C × N × Y	–	–	–	–	–	–	0.62	0.81	0.87

* Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.

used to describe repeated measures covariance in all analyses. Water table, cultivar, N, and crop-growth cycle were regarded as fixed effects, and replication was regarded as a random effect.

Significant effects identified by analysis of variance were further analyzed by separating least square means with t tests or LSD. The contrast statement in SAS was used to make single degree–of-freedom comparisons to test the significance of linear regressions on the target water-table depths of 23, 37, and 51 cm. Regressions were calculated using recorded water-table depths that differed moderately from target depths (Table 1). To simplify the presentation of results, target depths of 23, 37, and 51 cm are used in tables and graphs. Values of R^2 were calculated according to procedures described by Steel and Torrie (1960) using least square means generated via SAS. Differences were identified as significant at $P \leq 0.05$ and as highly significant at $P \leq 0.01$.

RESULTS AND DISCUSSION

Theoretical Recoverable Sucrose

Foliar N applications and interactions with foliar N did not affect TRS in the combined or individual crop-growth cycle analyses (Table 2). For nonflooded treatments across crop-growth cycles and cultivars, every centimeter increase of water-table depth decreased TRS by 0.13 g sucrose kg^{-1} cane ($P < 0.01$) (Fig. 1). The TRS of the periodically flooded treatment was similar to the TRS of each other water-table treatment in the plant crop (Table 3). In the first-ratoon crop, the TRS of the periodically flooded treatment was lower than the TRS values at constant water-table depths of 23 and 37 cm. This suggests that when not periodically flooded, increasingly shallow water-table depths increased TRS, but the second of two consecutive crop-growth cycles of periodic floods reduced TRS. Kang et al. (1986) reported that TRS increased when water-table depth was reduced from 56 to 30 cm. The present study corroborates these results and extends the shallow water-table depth from 30 to 23 cm. Glaz et al. (2004) reported that TRS did not respond to water-table depths of 16, 33, and 50 cm, but these water-table depths included periodic 1-wk floods. The positive response reported here of TRS to increasingly shallow water-table depths that were not periodically flooded suggests that the periodic 1-wk floods applied by Glaz et al. (2004) negated what
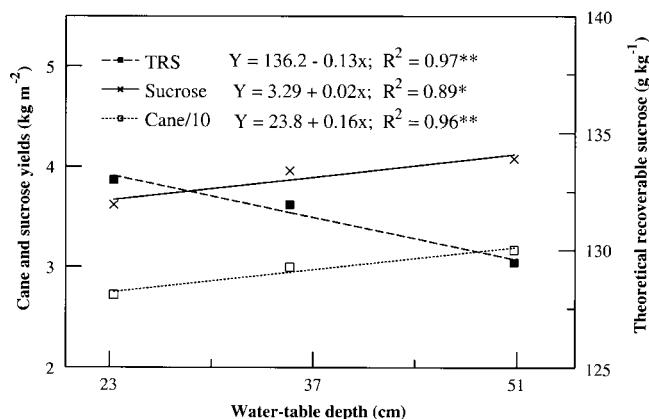

Fig. 1. Combined plant- and first-ratoon crop theoretical recoverable sucrose (TRS), cane yield, and sucrose yield responses of sugarcane cultivars CP 72-2086 and CP 80-1827 to water-table depth.

Table 3. Theoretical recoverable sucrose (TRS) for four water-table treatments and two sugarcane cultivars in the plant- (2001) and first-ratoon crops (2002).

Treatment†	2001	2002	Mean
		g kg^{-1}	
23 cm	138.4 A‡	127.6 A	133.0 A
37 cm	135.3 AB	128.6 A	132.0 A
51 cm	134.6 B	124.3 B	129.5 B
44 cm and flood	135.6 AB	123.3 B	129.5 B
CP 72-2086	134.0	124.0	129.0
CP 80-1827	138.0	127.9	132.9
$P > t$	0.01	0.01	<0.01

† Target water-table depths were 23, 37, and 51 cm always and 44 cm for 12 d followed by flood for 2 d for eight cycles in each crop growth cycle. Sugarcane cultivars were CP 72-2086 and CP 80-1827.
‡ Least square means of water-table treatments in the same column followed by the same letter are not significantly different based on LSD (0.05).

Table 4. First-ratoon crop cane and sucrose yields of two sugarcane cultivars subjected to four water-table and two nitrogen treatments.

Treatment†	Cultivar	N‡	Cane yield		Sucrose yield	
		kg ha^{-1}	kg m^{-2}			
23 cm	CP 72-2086	mean	24.16	E§	3.03	C
23 cm	CP 80-1827	mean	27.19	CDE	3.53	BC
37 cm	CP 72-2086	mean	30.68	ABC	3.88	AB
37 cm	CP 80-1827	mean	26.03	DE	3.40	BC
51 cm	CP 72-2086	mean	34.93	A	4.26	A
51 cm	CP 80-1827	mean	30.21	BCD	3.82	AB
44 cm and flood	CP 72-2086	mean	30.99	ABC	3.80	AB
44 cm and flood	CP 80-1827	mean	31.87	AB	3.96	AB
23 cm	mean	0	26.77	CD	3.42	BC
23 cm	mean	45	24.58	D	3.13	C
37 cm	mean	0	26.09	CD	3.33	C
37 cm	mean	45	30.62	ABC	3.96	AB
51 cm	mean	0	32.14	AB	3.98	AB
51 cm	mean	45	33.00	AB	4.10	A
44 cm and flood	mean	0	33.46	A	4.14	A
44 cm and flood	mean	45	29.40	BCD	3.61	ABC

† Target water-table depths were 23, 37, and 51 cm always and 44 cm for 12 d followed by flood for 2 d for eight cycles.
‡ Foliar N was applied once every 14 d, eight times in each crop cycle, at 0 and 5.6 kg ha^{-1}.
§ Least square means of water-table by cultivar and water-table by N treatments in the same column followed by the same letter are not significantly different based on LSD (0.05).

may have been positive effects on TRS of increasingly shallow water-table depths.

Cane Yield

The main effect of foliar N did not affect cane yields in the combined or individual crop-growth cycle analyses (Table 2). However, foliar N applied to the periodically flooded treatment in the first-ratoon crop reduced cane yield from 33.46 to 29.40 kg m^{-2} (Table 4).

In the plant crop, the cane yield of the periodically flooded water treatment was higher than the cane yield of each continuously drained treatment (Table 5). For nonflooded treatments, cane yield did not respond linearly to water-table depth, and water-table depth did not interact significantly with cultivar in the plant crop (Table 2). In the first-ratoon crop, cane yields of both cultivars were similar under the periodically flooded treatment (Table 4). However, for the nonflooded treatments in the first-ratoon crop, cultivar and water-table depth interacted significantly (Table 2). An explanation of this interaction is that the first-ratoon cane yield of CP 80-1827 was not affected by water-table depth, whereas the cane yield of CP 72-2086 increased by 0.38 kg m^{-2} for each centimeter increase in water-table depth from 23 to 51 cm (Fig. 2).

Table 5. Yields of cane and sucrose in the plant crop for four water-table treatments and two sugarcane cultivars.

Treatment†	Cultivar	Cane yield		Sucrose yield	
		kg m^{-2}			
23 cm	mean	28.73	B‡	3.97	B
37 cm	mean	31.59	B	4.27	B
51 cm	mean	30.68	B	4.12	B
44 cm and flood	mean	38.39	A	5.20	A
Mean	CP 72-2086	37.62		5.05	
Mean	CP 80-1827	33.29		3.47	
P > t		<0.01		<0.01	

† Target water-table depths were 23, 37, and 51 cm always and 44 cm for 12 d followed by flood for 2 d for eight cycles.
‡ Least square means of water-table treatments in the same column followed by the same letter are not significantly different based on LSD (0.05).

For nonflooded treatments, the linear response of cane yield to water-table depth was highly significant for the combined plant and first-ratoon crops (Table 2). Although the water table by crop-growth cycle interaction was significant, the linear responses to water-table depth for nonflooded treatments were similar in the plant and first-ratoon crops. Thus, for nonflooded treatments, in addition to the highly significant linear response in cane yield of CP 72-2086 in the first-ratoon crop, it is also important to consider the linear response to water-table depth combined over crop-growth cycles and cultivars. This response indicated that mean cane yields increased by 0.16 kg m^{-2} for each centimeter increase in water-table depth ($P < 0.01$) (Fig. 1). This was similar to the response reported by Glaz et al.
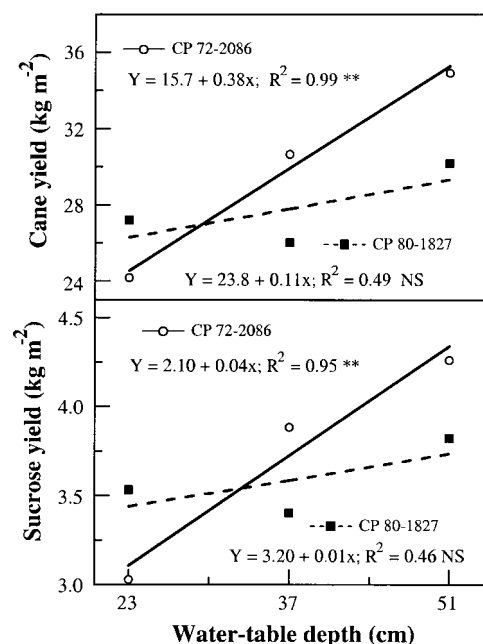
Fig. 2. First-ratoon crop cane and sucrose yield responses to water-table depth of sugarcane cultivars CP 72-2086 and CP 80-1827.

(2004) for a genotype without constitutive stalk aeren-chyma that was exposed to five or nine 7-d floods per year and drained to water-table depths similar to those used in the current study. Because these treatments in the current study did not include periodic flooding, the combined results of these two studies suggest that in-creasingly shallow water-table depths, with and without periodic flooding, have similar effects on cane yields.

For nonflooded treatments, increasingly shallow water-table depths from 51 to 23 cm were generally detrimental to cane yields, but eight periodic 2-d floods drained to 44 cm during nonflood periods resulted in higher cane yields compared with those of the non-flooded treatments, particularly in the plant–crop cycle (Table 5). In the first-ratoon crop, periodic flooding of CP 80-1827 resulted in increased cane yields compared with its yields at constant 23- and 37-cm water-table depths (Table 4). For CP 72-2086 in the first-ratoon crop, periodic flooding resulted in increased cane yields com-pared with the constant water-table depth of 23 cm. Cane yields of both cultivars responded well to periodic floods in the plant crop, but the residual effects of the plant–crop exposures were apparently more detrimental to the first-ratoon cane yields of CP 72-2086 than CP 80-1827. However, periodic flooding did not reduce first-ratoon cane yields for either cultivar compared with those of its nonflooded treatments.

Sucrose Yield

The water table by N interaction significantly affected sucrose yields in the first-ratoon crop (Table 2). An explanation for this interaction is that foliar N increased sucrose yield at the 37-cm water-table depth but not for any other water-table treatment (Table 4). First-ratoon cane yields were reduced by supplemental N in the pe-riodically flooded treatment. It can be inferred that foliar N applications had no consistent effect on yields, even at high water tables where it would be expected that season-long N would be less than the 686 kg N ha^{-1} that Terry (1980) estimated would be available for every centimeter of soil lost due to microbial oxidation.

For nonflooded treatments across cultivars and crop-growth cycles, for every centimeter increase in water-table depth, sucrose yield increased by 0.02 kg m^{-2} ($P =$ 0.03) (Fig. 1). This response is similar to that reported by Glaz et al. (2004) for a genotype without constitutive stalk aerenchyma exposed to five or nine 7-d floods per year and drained to water-table depths ranging from 16 to 50 cm.

Sucrose yields were similar among nonflooded water-table treatments in the plant crop (Table 2). However, the sucrose yield of the periodically flooded treatment in the plant crop was significantly higher than the sucrose yield at each of the three nonflooded water-table depths (Table 5). In the first-ratoon crop, the sucrose yield of the periodically flooded treatment for each cultivar was similar to its other sucrose yields except that the sucrose yield of the periodically flooded CP 72-2086 was greater than its sucrose yield at a constant water-table depth of 23 cm (Table 4).

For nonflooded treatments, responses of sucrose yield to water-table depth differed between CP 72-2086 and CP 80-1827 in the first-ratoon crop (Table 2). Sucrose yields of CP 72-2086 increased by 0.04 kg m^{-2} for every centimeter increase of water-table depth ($P = 0.01$) (Fig. 2). Water-table depth did not affect CP 80-1827 sucrose yields in the first-ratoon crop. As did cane yield responses to water-table depth for the nonflooded treat-ments, these sucrose yield responses indicate that the tolerance of CP 72-2086 to consecutive crop-growth cycles of shallow water tables was less in the first-ratoon than in the plant crop. For CP 72-2086 exposed to sum-mer water-table depths in a field study, cane and sucrose yields declined similarly (although not significantly) due to exposure to a shallow water-table depth from the plant to the first-ratoon crop (Glaz et al., 2002).

It is possible that results of this study were affected by confounding of crop-growth cycle (plant crop and first-ratoon crop) and year effects. However, several explan-ations suggest that responses in different years were due more to crop-growth cycle than year. First, it would be expected that shallow water-table depths applied con-secutively to the plant and first-ratoon crops would have more negative effects on yields in the first-ratoon than in the plant crop, as occurred in this study. Second, the declines in tolerance of CP 72-2086 to consecutive crop-growth cycle exposures to shallow water-table depth were similar in this study and in the study of Glaz et al. (2002). Finally, there were several similar cane and suc-rose yield responses to water-table depth in this study and that of Glaz et al. (2004).

Stalks of the two cultivars were not inspected for aer-enchyma formation in this study. In a previous study, formation of constitutive stalk aerenchyma occurred in one of two genotypes (CP 95-1429), and this genotype was not affected by periodic flooding and water-table depths of 16, 33, and 50 cm (Glaz et al., 2004).

CONCLUSIONS

In this lysimeter study, for sugarcane that was not periodically flooded, mean cane and sucrose yields ac-ross two crop-growth cycles and two cultivars increased as water-table depth increased from 23 to 51 cm. How-ever, in the first-ratoon crop, increasingly shallow water-table depths were more detrimental to CP 72-2086 yields than to those of CP 80-1827. Combined results of this and a previous study suggest that sugarcane yield losses caused by shallow water-table depths from 16 to 37 cm are not exacerbated by short-duration periodic flooding. Further, 2-d periodic floods drained to 44 cm resulted in cane and sucrose yield increases in the plant-crop for both cultivars and did not decrease cane or sucrose yields in the first-ratoon crop compared with yields at water-table depths of 23, 37, and 51 cm that were not periodically flooded. Phosphorus discharge from EAA farms is reduced by decreased pumping to public canals (Sievers et al., 2003; Daroub, S.H., T.A. Lang, O.A. Diaz, M. Chen, and J.D. Stuck, unpublished data, 2004). The information that repeated 2-d floods increased sugarcane yields should help reduce P discharge from

the EAA to the natural Everglades by lessening the urgency to pump water from farm to public canals when fields are flooded.

REFERENCES

Cisar, J.L., G.H. Snyder, and G.S. Swanson. 1992. Nitrogen, phosphorus, and potassium fertilization for Histosol-grown St. Augustinegrass sod. Agron. J. 84:475–479.

Coale, F.J., C.A. Sanchez, F.T. Izuno, and A.B. Bottcher. 1993. Nutrient accumulation and removal by sugarcane grown on Everglades Histosols. Agron. J. 85:310–315.

Glaz, B. 2002. Sugarcane variety census: Florida 2001. Sugar J. 65:35–39.

Glaz, B., S.J. Edme, J.D. Miller, S.B. Milligan, and D.G. Holder. 2002. Sugarcane cultivar response to high summer water tables in the Everglades. Agron. J. 94:624–629.

Glaz, B., D.R. Morris, and S.H. Daroub. 2004. Periodic flooding and water table effects on two sugarcane genotypes. Agron. J. 96: 832–838.

Glaz, B., P.Y.P. Tai, J.D. Miller, and J.R. Orsenigo. 1990. Registration of 'CP 80-1827' sugarcane. Crop Sci. 30:232–233.

Kang, M.S., G.H. Snyder, and J.D. Miller. 1986. Evaluation of *Saccharum* and related germplasm for tolerance to high water table on organic soil. J. Am. Soc. Sugar Cane Technol. 6:59–63.

Legendre, B.L., 1992. The core/press method for predicting the sugar yield from cane for use in cane payment. Sugar J. 54:2–7.

Miller, J.D., P.Y.P. Tai, B. Glaz, J.L. Dean, and M.S. Kang. 1984. Registration of 'CP 72-2086' sugarcane. Crop Sci. 24:210.

Morris, D.R., B. Glaz, and S.H. Daroub. 2004. Organic soil oxidation potential due to periodic flood and drainage depth under sugarcane. Soil Sci. 169:600–608.

Omary, M., and F.T. Izuno. 1995. Evaluation of sugarcane evapotranspiration from water table data in the everglades agricultural area. Agric. Water Manage. 27:309–319.

Sanchez, C.A. 1990. Soil-testing and fertilization recommendations for crop production on organic soils in Florida. Bull. 87. Univ. of Florida, Gainesville, FL.

SAS Institute. 2003. SAS Version 9.0. SAS Institute, Cary, NC.

Shih, S.F., B. Glaz, and R.E. Barnes, Jr. 1998. Subsidence of organic soils in the Everglades Agricultural Area during the past 19 years. Proc. Soil Crop Sci. Soc. Fla. 57:20–29.

Sievers, P., D. Pescatore, S. Daroub, J.D. Stuck, J. Vega, P. McGinnes, and S. Van Horn. 2003. Performance and optimization of agricultural best management practices, Everglades consolidated report, water year 2002. Chapter 3. South Florida Water Management District, West Palm Beach, FL. Available at www.sfwmd.gov/org/ema/everglades/consolidated_03/ecr2003/chapters/ch3.pdf (verified 10 Jan. 2006).

Snyder, G.H., and J.M. Davidson. 1994. Everglades agriculture, past, present, and future. *In* S.M. Davis and J.C. Ogden (ed.) Everglades: The ecosystem and its restoration. St. Lucie Press, Delray Beach, FL.

Steel, R.G.D., and J.H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill, New York.

Tao, J., R. Littell, M. Patetta, C. Truxillo, and R. Wolfinger. 2002. Mixed models analyses using the SAS system: Course notes. SAS Institute, Cary, NC.

Terry, R.E. 1980. Nitrogen mineralization in Florida Histosols. Soil Sci. Soc. Am. J. 44:747–750.